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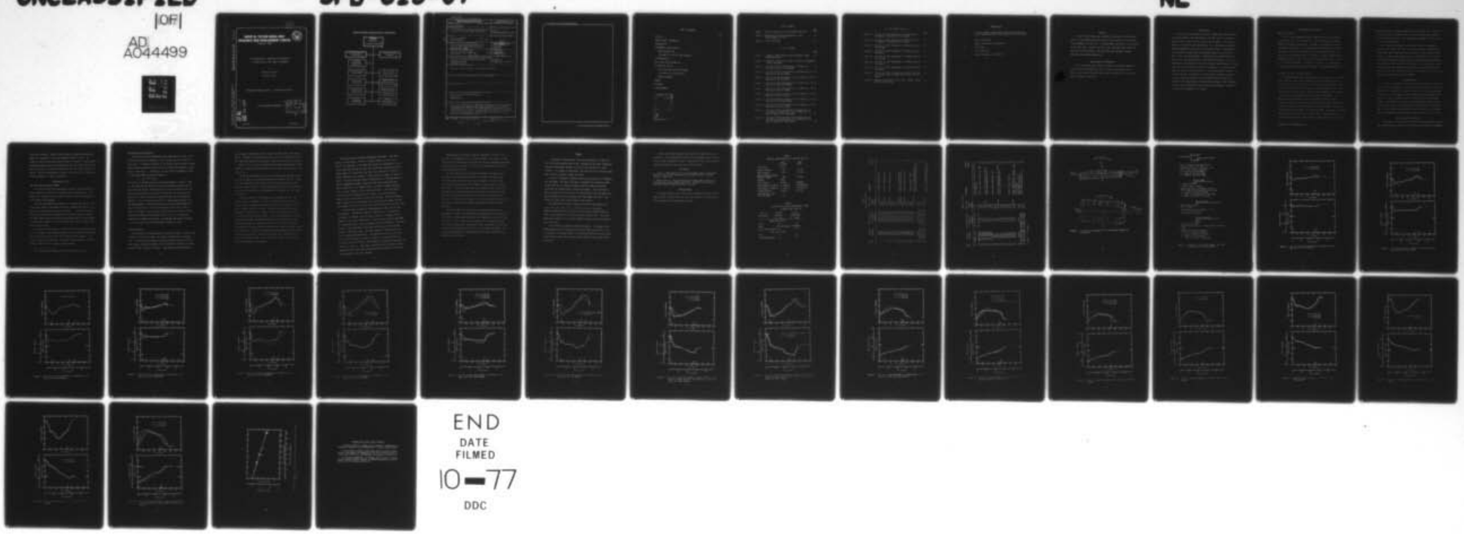

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20084

THE OVERLAND GULLY, RAMP AND STEP RESPONSE OF THE AALC JEFF (A) ACV, MODEL EXPERIMENTS

by

Lawrence O. Murray

David D. Moran

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SHIP PERFORMANCE DEPARTMENT

June 1977

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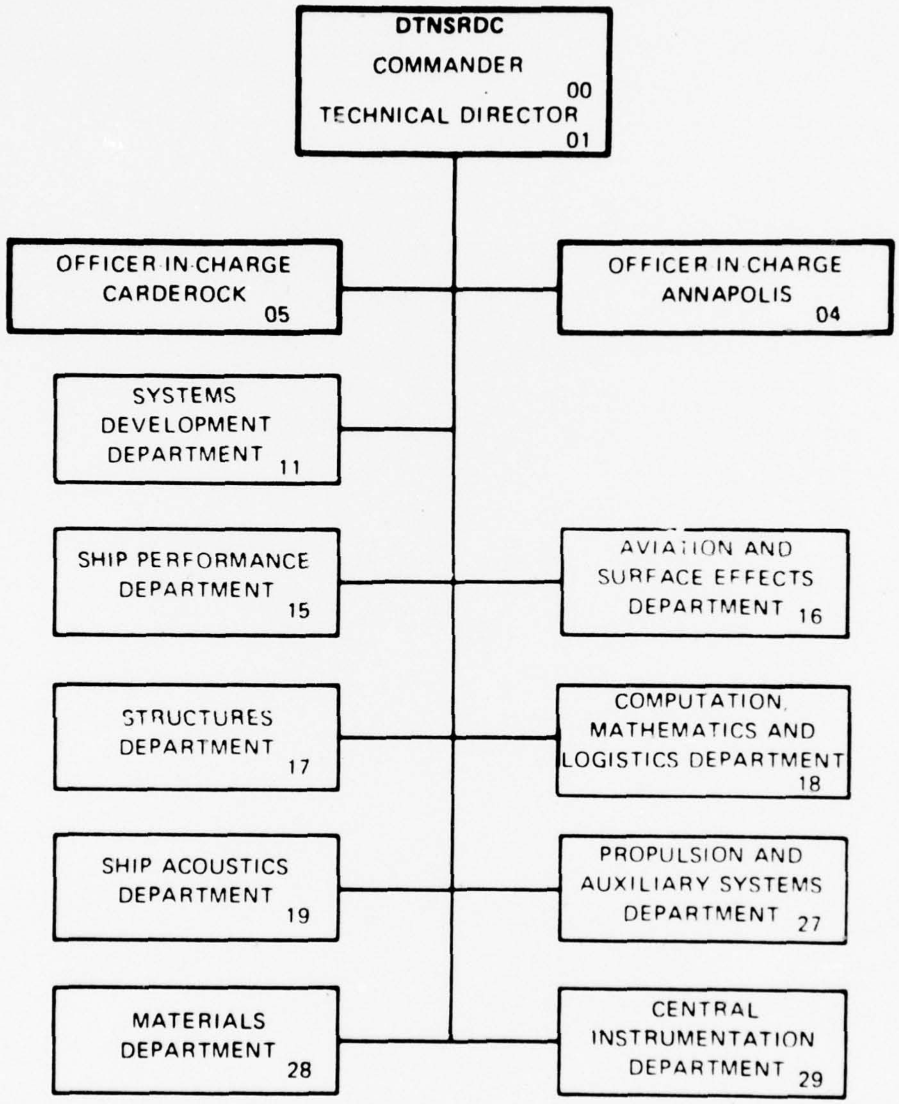

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A series of experiments was performed to evaluate the overland behavior of the Amphibious Assault Landing Craft Program Air Cushion Vehicle designated as the JEFF (A). The experiments consisted of free passages of the craft over a series of gullies, ramps, and steps and allowing the vehicle to pitch and heave. The resultant pitch and heave response functions are presented graphically.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

NOMENCLATURE

x	Distance between leading edge of bow skirt cell and the initial transition point of the terrain, positive forward
z	Heave displacement
β	Damping coefficient, see equation 1
θ	Pitch angle
θ_o	Pitch amplitude
ω_n	Natural frequency, see equation 1

ABSTRACT

A series of experiments was performed to evaluate the overland behavior of the Amphibious Assault Landing Craft Program Air Cushion Vehicle designated as the JEFF (A). The experiments consisted of free passages of the craft over a series of gullies, ramps, and steps and allowing the vehicle to pitch and heave. The resultant pitch and heave response functions are presented graphically.

ADMINISTRATIVE INFORMATION

This investigation was funded by the Naval Sea Systems Command and administered by the Amphibious Assault Landing Craft Program of the David W. Taylor Naval Ship R&D Center under Task Area S1417, Task 14174, Work Unit Number 1-1180-740.

INTRODUCTION

The mission of the Amphibious Assault Landing Craft (AALC) Program Air Cushion Vehicle (ACV) designated as the JEFF (A) is to transport material from a ship to an off-loading site on a beach. The craft must operate in an overland environment where it is subjected to excitation from the geometrical variations in the ground terrain. These geometrical variations include large non-deformable objects such as gullies, walls, logs, and large boulders. Depending on size, the obstacles may give rise to large motion which may be modeled nonlinearly, or it may impede the craft completely (the limiting case of nonlinearity). For example, the craft may ride over a wall, be stopped by it, or be deflected away from a wall on a new trajectory. The overland dynamic behavior of the JEFF (A) was investigated in an experimental program at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). The results of the experiment are discussed qualitatively in the following sections and the quantitative motion data are presented as trajectories in the figures appended to this report.

EXPERIMENTAL INVESTIGATION

MODEL DESCRIPTION

The air-cushion-supported vehicle chosen from this experimental investigation is a .07 scale model of a 150-ton (design displacement) Amphibious Assault Landing Craft. The model, constructed by the Aero-jet-General Corporation, is a dynamic model of the AALC JEFF (A) design. The vehicle is a fully-skirted ACV which is designed to operate over water, over solid terrain, and in surf zones. The basic dimensions and dynamic properties of the JEFF (A) model as tested are listed in Table 1. A sketch of the model is presented in Figure 1. A complete description of the model skirt and lift system is presented in Reference 1.*

OVERLAND TEST FACILITY AND PROCEDURE

The overland experimental test facility was located on the concrete apron along the north side of the Maneuvering and Seakeeping Facility (MASK) at the David W. Taylor Naval Ship Research and Development Center. The test track consisted of a nylon cord stretched between pylons at the extreme ends of the test area. Vertical plates containing slots in which the cord fit were attached to the bow and stern of the model. The model was accelerated prior to a run by pulling on two tow ropes attached to the bow. When the desired speed was achieved, the model was allowed to coast at constant velocity over the test element. Dynamically, the model was free to pitch, roll, heave and surge. In practice, the model was found to show little roll or surge response. The power required to operate the lift fans was supplied from a solid state 400 cycle generator

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*References are listed on page 11

through an electrical cable attached to one of the tow lines. Data from the model-mounted instruments were transmitted through cables attached to the alternate tow line. The signals were displayed as time histories on a strip chart recorder.

The rigid terrain elements consisted of a series of separately tested gullies, ramps, and steps. The major variables of interest were: craft speed, gully length and depth, ramp height, ramp slope, and step height. In order to make these variations efficiently, easily, and in a cost-effective manner, wooden ramps and platforms were used that were constructed for the experiments of Reference 2. The ground terrain over which the experiments were performed and the step platforms were horizontal and level with height variations of no more than 0.2 cm (1/16 inch) model scale, over the test section length.

INSTRUMENTATION

The craft instrumentation consisted of three ultrasonic displacement center-receiver transducers. Two were mounted in the vertical direction equidistant from the JEFF (A) center of gravity, one on the bow and one on the stern. These probes were used to measure pitch and heave motion. The third probe was mounted in the horizontal direction and directed forward. The horizontal unit was used to measure the distance traveled as a function of time. The average slope of the distance curve with respect to time was used to determine the speed for each run. A manometer was used to determine static bag and cushion pressures prior to testing.

DATA COLLECTION AND ANALYSIS

Time histories of the output of the three ultrasonic probes plus the sum and difference of the two vertical probes were collected on a Sandborn

strip chart recorder. Values of pitch, heave, distance travelled, and speed as a function of time were obtained from this record. The values of pitch and heave were then plotted as functions of the distance, x, travelled relative to an origin defined for the bow fingers encountering the first point of a transition and defined positive in the direction of motion. The plots obtained were scaled to full scale JEFF (A) dimensions and are presented in Figures 3 through 20.

EXPERIMENTAL RESULTS

ZERO SPEED AND LOW SPEED RESPONSE

The first portion of the experimental study was concerned with the gross capability of the craft to negotiate step discontinuities. Step heights of 1.18* metre (3.87 ft) and 1.81 metre (5.95 ft) were used for this portion of the program.

The JEFF (A) ascends and descends the 1.18 metre step with no difficulty at any speed in the forward direction ; however the craft will not back over a step discontinuity of this height. During a backing operation, the stern cells collapse and then the hard structure contacts the step. Giving the craft a small yaw angle does not aid in the passage. If a 45^{0} ramp is placed in front of the step, the craft is found to back easily over the ramp.

The craft will not ascend a 1.81 metre (5.95 ft) step from any direction at low speed. Also, when descending, the craft hard structure under the vehicle hits, and the craft slides along the hard structure. The craft is capable of traversing a 1.81 metre 45^{0} ramp, however, in either direction with little or no hard structure contact.

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* All values in this report are full scale except as noted.

DECLINING OSCILLATION RESULTS

Declining oscillation experiments were conducted over a level rigid surface for oscillation response in pitch, heave, and roll at zero forward speed. The temporal responses of the bow and stern ultrasonic probes were recorded and the data were analyzed to compute the frequency, ω_n and damping coefficient β. The behavior of the craft was assumed to follow a simple decay model as given by Equation 1.

$$\theta(t) = \theta_o e^{-\beta(\theta_o)t} \cos\omega_n t \qquad (1)$$

The results of the declining oscillation experiments are shown in Table 2. The value for the pitch oscillation was obtained by depressing and then releasing the bow. Heave response could not be obtained since the damping characteristic of the JEFF (A) overland is so large that less than one full cycle of motion was measurable with the instrumentation employed. The roll natural period and roll damping were obtained from the heave reading. This was made possible since the characteristic motion of the JEFF (A) in roll is such that the craft sinks as the roll angle is increased. The roll decay coefficient given in Table 2 should therefore be taken as an approximation only since it is based upon a combined roll induced heave motion. As expected, the natural frequency in roll is higher than the corresponding frequency in pitch.

TERRAIN RESPONSE

The third part of the experimental program consisted of forward speed passages of the JEFF (A) model over various discrete terrain configurations. The obstacles used were constructed from two platforms with vertical edges 0.63 metre in height, similar platforms 1.18 metre in height, and a 45^o ramp 1.18 metre in height. These obstacles were combined in

various ways to obtain the gullies, steps, and ramps used in the investigation. Examples of the various obstacles used in the program along with the significant events for each type of obstacle are presented in Figure 2. Table 3 lists all runs and conditions which were examined and includes comments on important events observed such as hard structure impacts with the terrain.

During the preliminary runs, it was discovered that the model would not, in all cases, coast over the obstacles at constant velocity. Therefore, the model was pulled lightly while crossing the obstacles unless otherwise noted in Table 3. Runs in which the model did not complete the pass over the obstacle are not presented on the figures, but are noted in Table 3.

The first obstacles investigated were rectangular gullies. The gullies were of 2.18 metre (7.15 ft), 4.36 metre (14.29 ft) and 6.53 metre (21.43) in length and 0.63 metre (2.08 ft), 1.18 metre (3.79 ft), and 1.81 metre (5.95 ft) in depth. The data for the gully passes are presented in Figures 3-12. In general, the craft seems to cross the gullies most easily at higher speeds. This may be explained by the fact that for high speeds, the maximum bow down pitch attitude occurs after the bow passes the full length of the gully, i.e. at point A (second edge) whereas, at lower speeds, the maximum pitch down occurs when the bow is in the gully. Further, the maximum pitch displacement decreases with increasing craft speed. The craft also heaves less as the bow crosses the gully at higher speeds so the craft tends to bounce less violently when the second edge is encountered.

The second type of obstacles examined was a 45^{0} ramp. The ramps were at 0.55 metre and 1.18 metre in height leading to a level platform of the same height. The ramps were chosen for investigation since it was found that the vehicle could not consistently negotiate vertically faced steps of a height which was physically meaningful or which produced interesting craft response. These results are shown in Figures 13 and 14. The most important response characteristic is that the motion is nearly independent of speed. Both heave and pitch trajectories are nearly identical for all speeds tested. The second response characteristic of major interest is the linear heave motion. The craft experiences a vertical acceleration which results in a constant vertical heave velocity as the vehicle passes over the ramp. The main difference due to speed in the ramp response was a subjective one; namely that the force needed to pull the craft up the ramp decreased with increasing speed.

The third type of obstacles investigated was a step with vertical leading edge. The data are shown in Figures 15-19. The steps were 0.63 metre, 1.18 metre, and 1.81 metre in height. In general, the response to a vertically faced step is similar to the previously described 45^{0} slope ramp results, but with sharper transition responses. The heave motion is seen to be nearly linear with position as the craft either ascends or descends a step. The pitch response is smooth and regular for all speeds and step heights. The effect of an initial pitch angle on the vehicle response is shown in Figure 15 for the 14.68 knot run. A bow up initial trim angle of approximately 1 degree was produced by the tow lines in this run. Under these conditions the craft travels approximately one-half of the cushion length before the effects of the initial trim disappear in the pitch response.

Impact events can be seen in the runs presented in Figure 19 for the JEFF (A) descending from a 1.81 metre platform. For example, in the 10.66 knot run, the bottom of the craft hits the step repeatedly beginning some 30 feet aft of the bow (full scale) until two-thirds of the craft length has passed the step.

The final type of terrain obstacle tested was an irregular step consisting of vertical faced step with a 1.18 metre 45^{0} ramp on top. This obstacle was studied since it was found that a 1.81 metre step could not be crossed by the craft without at least a partial leading edge slope. It should be noted that even though the step could not be negotiated, the step-ramp produced no difficulty in the craft passage. The heave and pitch trajectories for this obstacle are presented in Figure 20. In general, the response is similar to the previous ramp and step results, but with the maximum angle reaching a slightly higher magnitude.

The heave response of the vehicle has been found to be nearly independent of speed. The relationship between heave and the geometry of the obstacle is determined primarily by the leakage of cushion air under the skirts. This is shown for the combined gully showing the maximum (or equilibrium heave where approximate) heave displacement as a function of the cross-sectional area of the gully (gully length and depth). The leakage area dependence is demonstrated by the linear relationship between these two variables.

SUMMARY

Experimental investigation of the overland behavior of AALC JEFF (A) air-cushion-supported vehicle has increased the available information concerning the dynamic response of this craft to passage over rigid surfaces. In a number of experiments, the craft was run at varying speeds over a series of gullies, ramps, and steps.

The JEFF (A) appears to negotiate easily most obstacles of reasonable size and shape. The ease of passage is increased with increasing speed as the craft has less time to respond inertially before equilibrium conditions are reestablished in the gully passages. Hard structure impacts are possible, but occur only for operation over terrains where they may be expected such as for passage over sharp edged steps with a step height as large as the cushion height of the vehicle.

The heave motion in each of the test series has been found to be linear with time. The craft is therefore subject to an approximately constant vertical velocity as it passes over overland obstacles. This is particularly true for the larger and uneven gullies. This characteristic response is also clearly evident for both ascents and descents over step faces.

Pitch response is generally smooth and regular. The greater pitch displacements occur for bow down motion rather than bow up motion. This is caused by the combined effects of the bow seal being more active dynamically than the stern seal and that cushion venting limits upward motion of the bow.

Finally, the heave response of the JEFF (A) to overland gully excitation is clearly determined primarily by the leakage area of the gully for the range of geometries tested. The effect of craft speed has been found to be minimal in the craft gully heave response.

REFERENCES

1. Fein, J. "Horizontal Plane Static and Dynamic Stability Characteristics of the JEFF (A) Amphibious Assault Landing Craft," DTNSRDC SPD-467-11, Nov 1975

2. Moran, David D. "The Overland Vertical Plane Dynamic Response of the AALC JEFF (B) ACV; Model Experiments", DTNSRDC Ship Performance Department Report Number SPD-615-04, June 1976

ACKNOWLEDGMENTS

The authors would like to express their appreciation to Mr. Daniel Huminik and Mr. William Dixon for their many essential contributions to the performance of the experimental program.

TABLE 1

PHYSICAL CHARACTERISTICS OF THE AALC JEFF (A)

	MODEL AS TESTED	FULL SCALE
SCALE RATIO	14.28	
LENGTH (OVERALL)	2.05m	29.20m
BEAM (OVERALL)	1.02m	14.63m
CUSHION LENGTH (CHARACTERISTIC LENGTH)	1.82m	26.03m
FAN RPM	10000	
DESIGN MASS, m	51.59kg	150400kg
PITCH MOMENT OF INERTIA	$15.44 kg\text{-}m^2$	$9.19 x 10^6 kg\text{-}m^2$
ROLL MOMENT OF INERTIA	$4.35 kg\text{-}m^2$	$2.58 x 10^6 kg\text{-}m^2$
CUSHION PRESSURE	313.1N/m	4473.N/m
PRESSURE RATIO (BOW BAG / CUSHION)	1.35	

TABLE 2

DECLINING-OSCILLATION EXPERIMENTS AT ZERO FORWARD SPEED, JEFF (A)

TYPE OF OSCILLATION	NATURAL FREQUENCY ω_n 1/sec	DECAY COEFFICIENT β 1/sec
MODEL SCALE VALUES		
PITCH	8.6	2.8
HEAVE	NOT OBTAINABLE, OVERDAMPED	
ROLL INDUCED HEAVE	16.5	3.5
FULL SCALE VALUES		
PITCH	2.3	0.7
ROLL INDUCED HEAVE	4.4	0.9

TABLE 3

LIST OF DATA RUNS

RUN NO.	TYPE OF OBSTACLE	FULL SCALE SIZE OF OBSTACLE (METRES)	FULL SCALE SPEED (KNOTS)	COMMENTS	FIGURE NUMBER
1	GULLY	2.18 by 0.63	3.3(start)	Did not complete pass	---
2	GULLY	2.18 by 0.63	6.05		3
3	GULLY	2.18 by 0.63	12.76		3
4	GULLY	4.36 by 0.63	3.0(start)	Did not complete pass	---
5	GULLY	4.36 by 0.63	5.93		4
6	GULLY	4.36 by 0.63	11.52		4
7	GULLY	6.53 by 0.63	7.9(start)	Did not complete pass	---
8	GULLY	6.53 by 0.63	13.88		5
9	GULLY	2.18 by 1.18	3.29		6
10	GULLY	2.18 by 1.18	6.27		6
11	GULLY	2.18 by 1.18	14.33		6
12	GULLY	4.36 by 1.18	2.2(start)	Did not complete pass	---
13	GULLY	4.36 by 1.18	6.11(adv.)	Model slowed at point A	7
14	GULLY	4.36 by 1.18	14.80		7
15	GULLY	6.53 by 1.18	5.78(adv.)	Model slowed at point A	8
16	GULLY	6.53 by 1.18	13.75		8
17	GULLY	2.18 by 1.81	6.45		9
18	GULLY	2.18 by 1.81	13.57	Model slightly yawed	9
19	GULLY	2.18 by 1.81	15.88		9
20	GULLY	4.36 by 1.81	2.96(adv.)	Start 7.9, model impacted at point A and slowed signficantly	10
21	GULLY	4.36 by 1.81	17.02		10
22	UNEVEN GULLY	2.18 by 1.81-1.18	4.59		11
23	UNEVEN GULLY	2.18 by 1.81-1.18	9.16		11
24	UNEVEN GULLY	2.18 by 1.81-1.18	17.24		11
25	UNEVEN GULLY	4.36 by 1.81-1.18	3.65(adv.)	Start 5.5, model impacted at point A and slowed signficantly	12

TABLE 3 (cont.)

RUN NO.	TYPE OF OBSTACLE	FULL SCALE SIZE OF OBSTACLE (METRES)	FULL SCALE SPEED (KNOTS)	COMMENTS	FIGURE NUMBER
26	UNEVEN GULLY	4.36 by 1.81-1.18	10.19	Model impacted at point a but did not slow down	12
27	UNEVEN GULLY	4.36 by 1.81-1.18	15.18		12
28	45° RAMP*	1.18	2.80	Model very hard to pull up ramp	14
29	45° RAMP*	1.18	7.57		14
30	45° RAMP*	1.18	14.94		14
31	45° RAMP*	1.18	7.43(adv.)	Start 11.9, did not pull model	14
32	45° RAMP*	0.55	3.05	Model needed moderate pull	13
33	45° RAMP*	0.55	7.88		13
34	45° RAMP*	0.55	15.38		13
35	STEP*	0.55	3.47	Model needed moderate pull	15
36	STEP*	0.55	10.24		15
37	STEP*	0.55	14.68		15
38	STEP*	1.18	5.2(start)	Did not complete pass, no impact	---
39	STEP*	1.18	7.35	Model needed moderate pull	16
40	STEP*	1.18	14.82		16
41	STEP**	1.18	5.34		17
42	STEP**	1.18	8.46		17
43	STEP**	1.18	6.61		17
44	STEP**	1.18	17.02	Model slightly yawed	18
45	STEP**	1.18	12.94		18
46	STEP**	1.81	4.5(start)	Model impacted and stopped	19
47	STEP**	1.81	10.66	Model impacted then scraped along on the skids	19
48	STEP**	1.81	14.87	Same comment as no. 47	19
49	STEP WITH RAMP	0.63step,1.18ramp	3.92	Model needed hard pull	20
50	STEP WITH RAMP	0.63step,1.18ramp	8.73	Model needed moderate pull	20
51	STEP WITH RAMP	0.63step,1.18ramp	14.69		20

* Ascent ** Decent

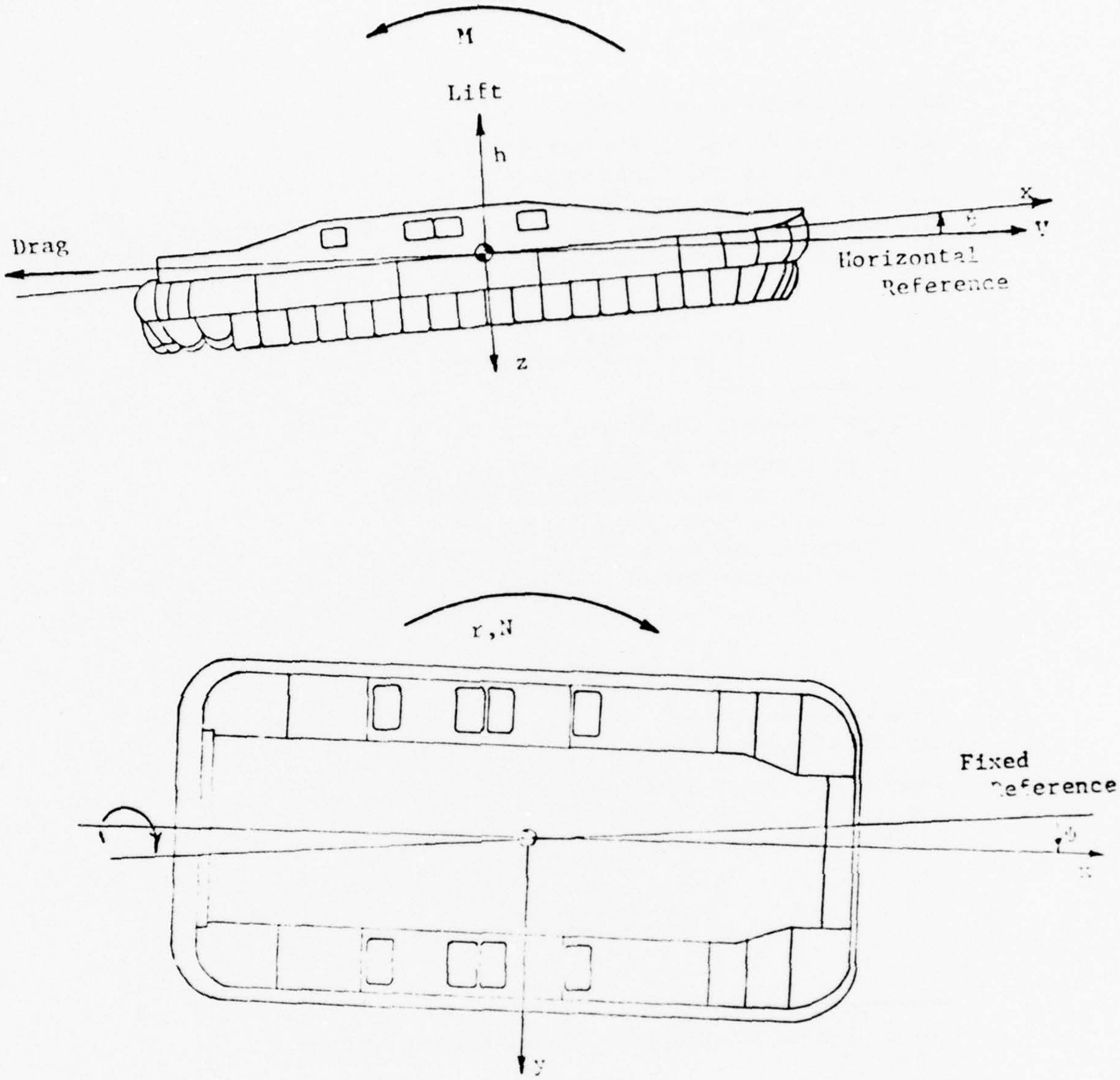
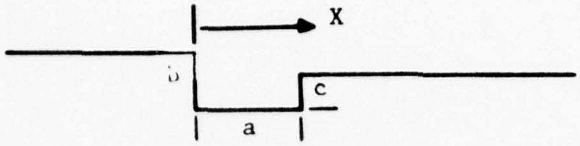
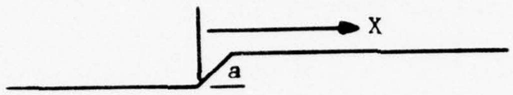


Figure 1 - Schematic Indicating Positive Directions of Measured Quantities



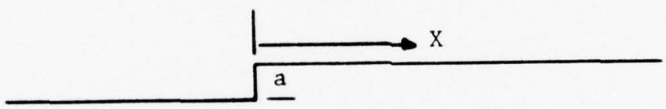
Gully of Length a and Depth b and c.

Signficant Events in Figures 3 -- 12;
X = 0 - Bow on the First Edge
A - Bow on the Second Edge
B - Stern on the First Edge
C - Stern on the Second Edge



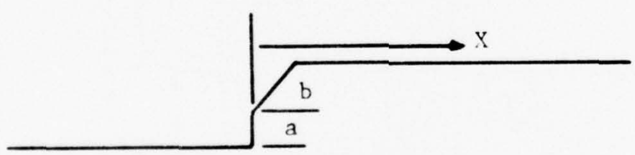
45 Degree Ramp of Height a

Signficant Events in Figures 13 and 14;
X = 0 - Bow at the Beginning of the Ramp
A - Bow at the End of the Ramp
B - Stern at the Beginning of the Ramp
C - Stern at the End of the Ramp



Step of Height a

Signficant Events in Figures 15 - 19;
X = 0 - Bow at the Step
A - Stern at the Step



Step of Height a with a 45 Degree Ramp of Height b on Top

Signficant Events in Figure 20;
X = 0 - Bow at the Step-Ramp
A - Bow at the End of the Ramp
B - Stern at the Step-Ramp
C - Stern at the End of the Ramp

Figure 2 - Examples of the Gullies, Ramps, and Steps Encountered in the Experiments.

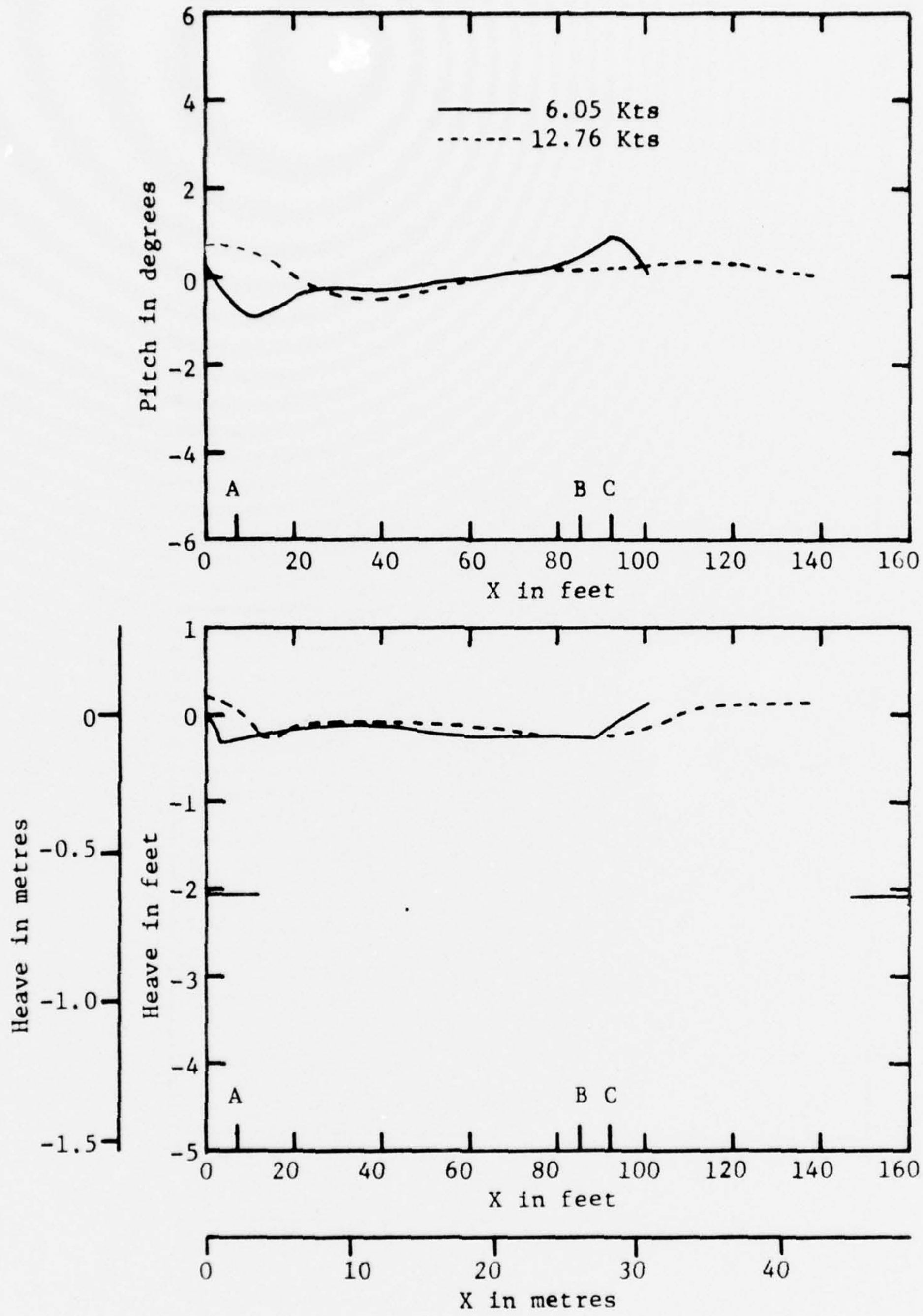


Figure 3 - The Jeff A AALC Encountering a 2.18 Metre by 0.63 Metre Gully for two Speeds.

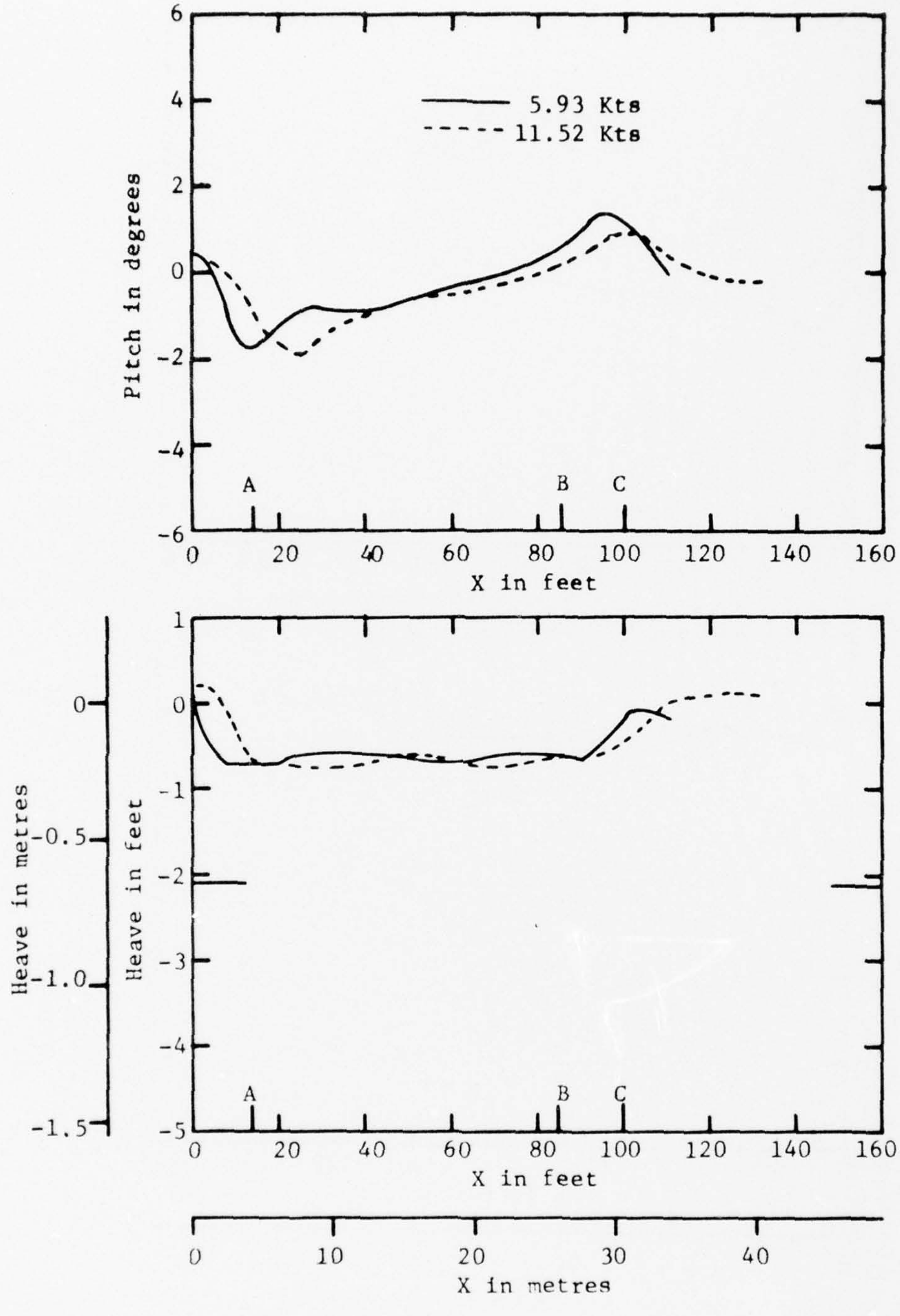


Figure 4 - The Jeff A AALC Encountering a 4.36 Metre by 0.63 Metre Gully for Two Speeds.

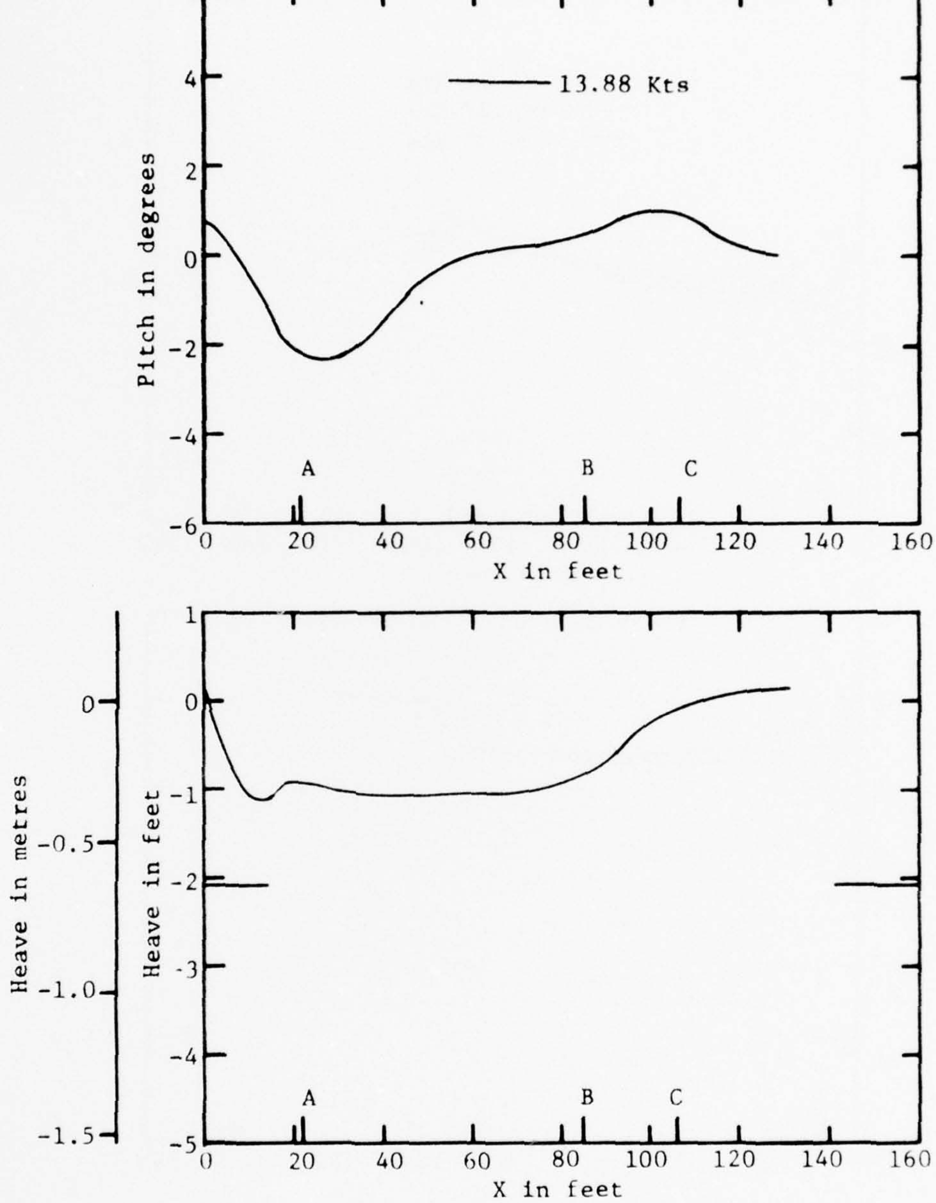


Figure 5 - The Jeff A AALC Encountering a 6.53 Metre by 0.63 Metre Gully for One Speed.

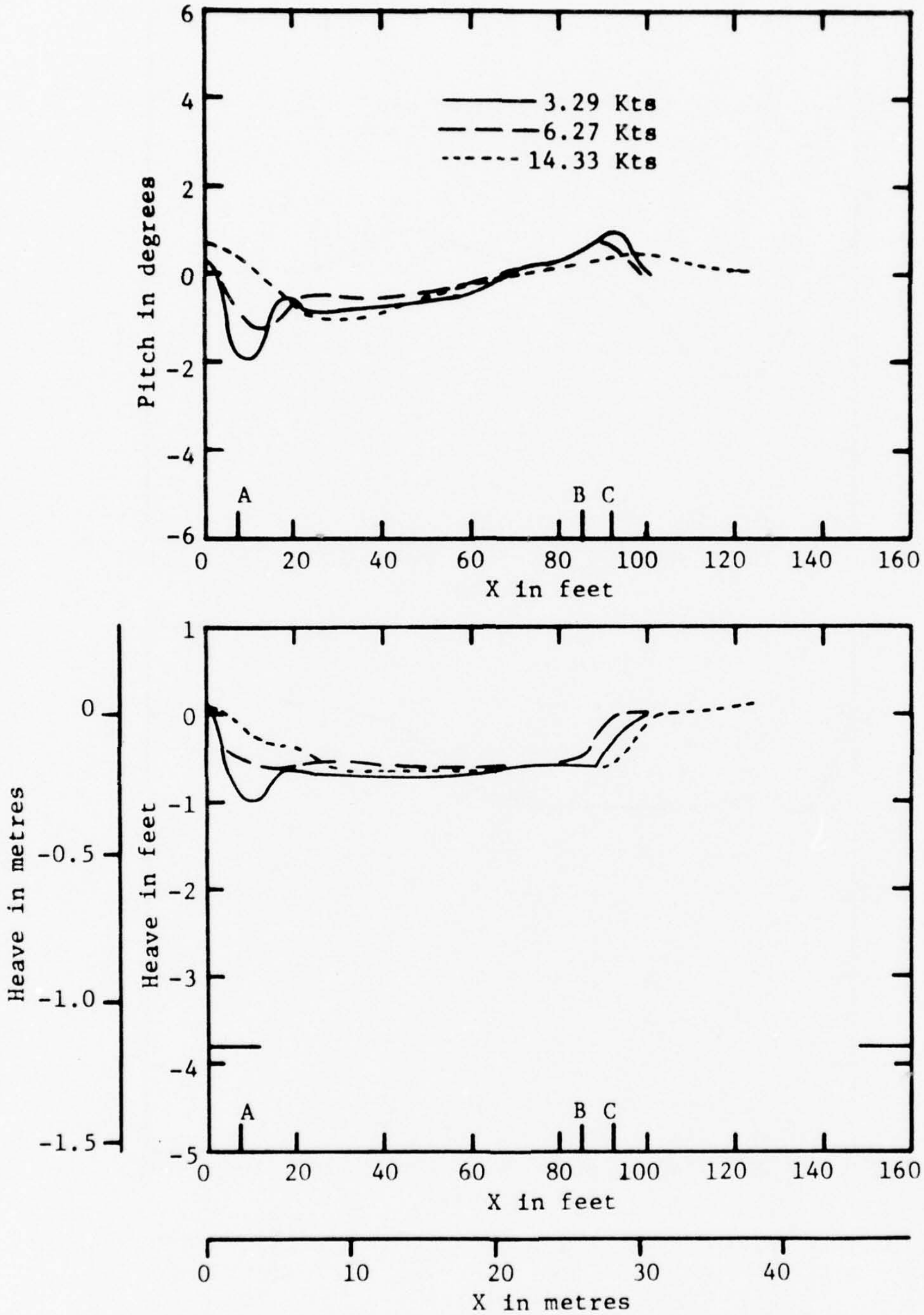


Figure 6 - The Jeff A AALC Encountering a 2.18 Metre by 1.18 Metre Gully for Three Speeds.

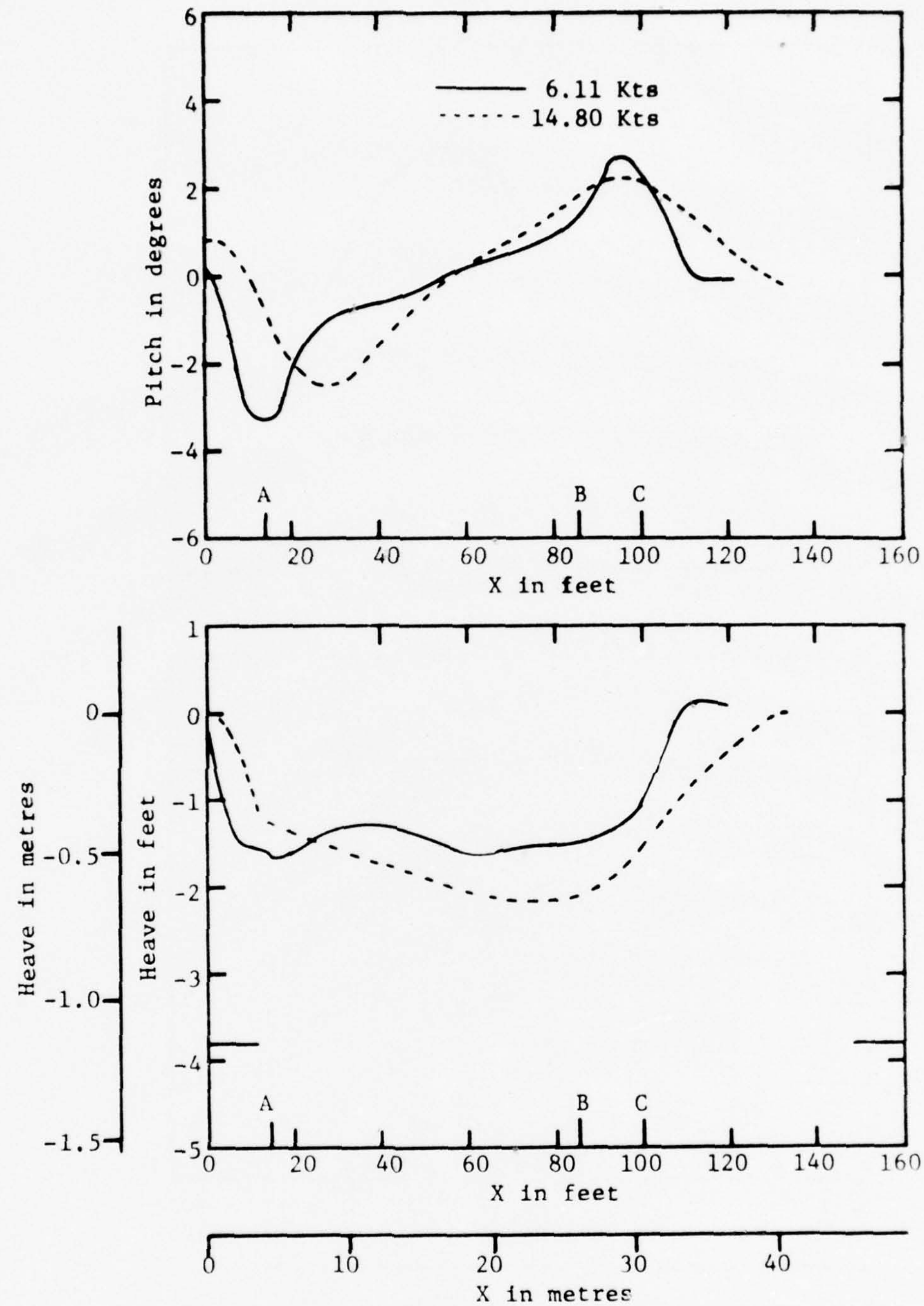


Figure 7 - The Jeff A AALC Encountering a 4.36 Metre by 1.18 Metre Gully for Two Speeds.

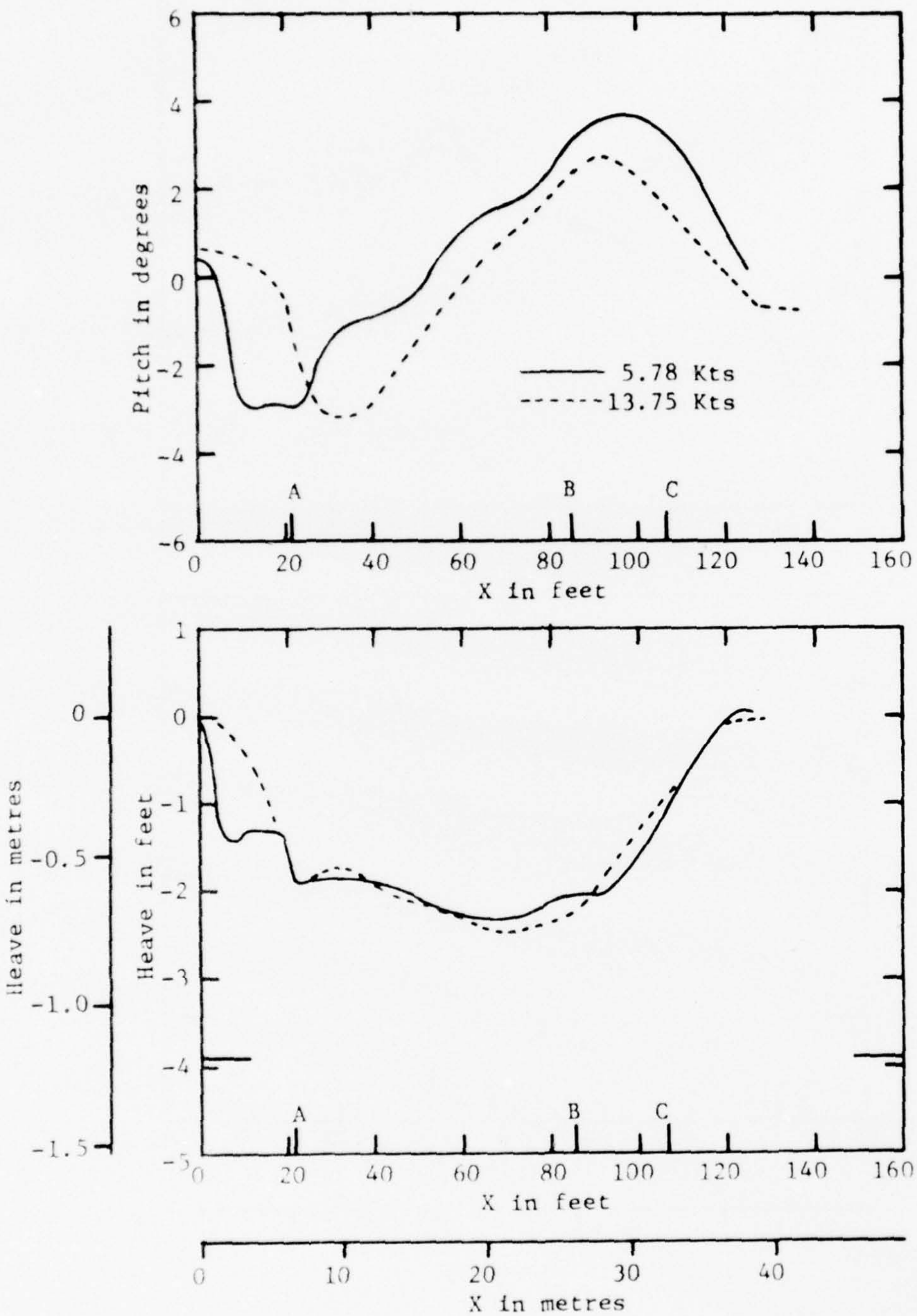


Figure 8 - The Jeff A AALC Encountering a 6.53 Metre by 1.18 Metre Gully for Two Speeds.

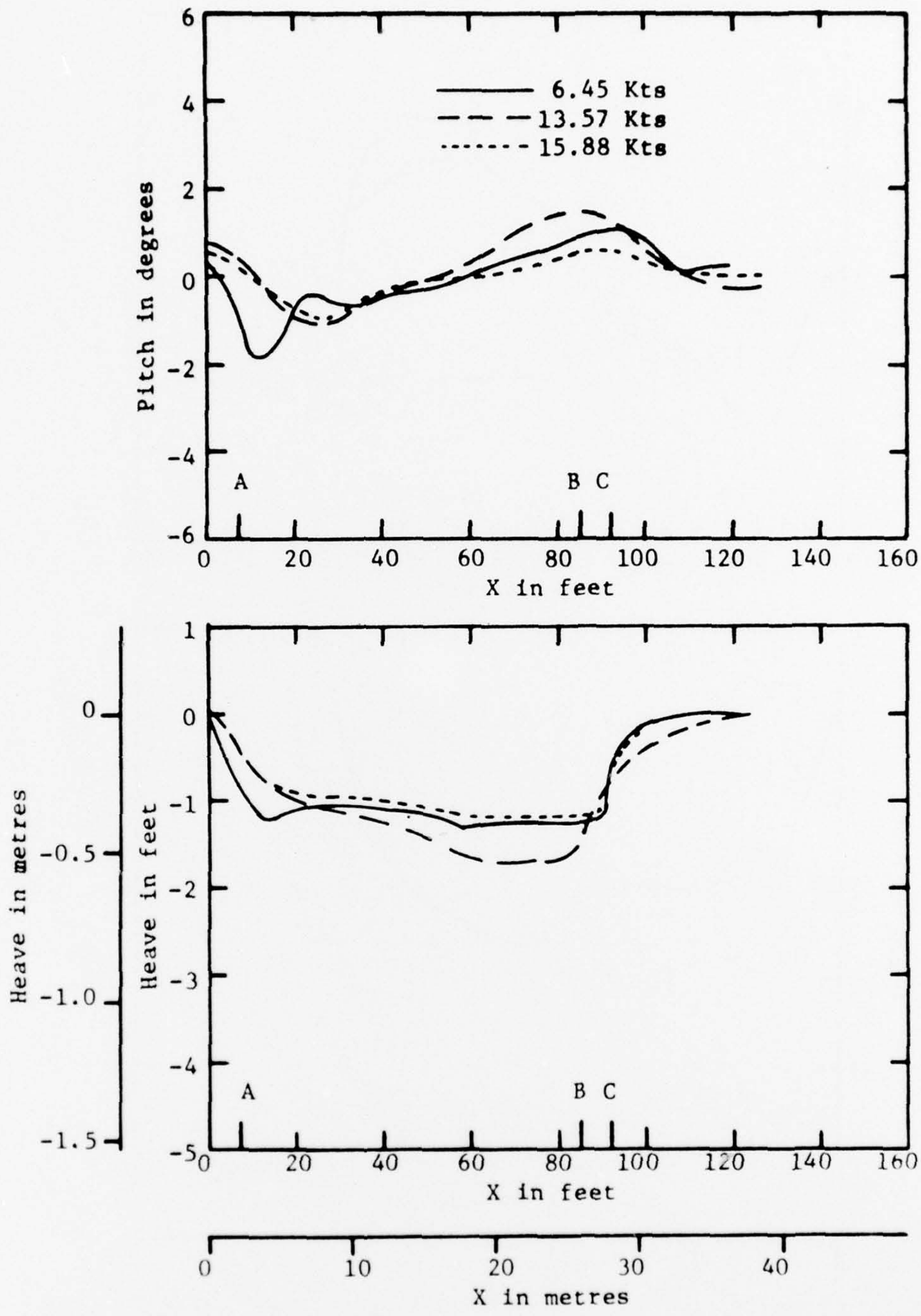


Figure 9 - The Jeff A AALC Encountering a 2.18 Metre by 1.81 Metre Gully for Three Speeds.

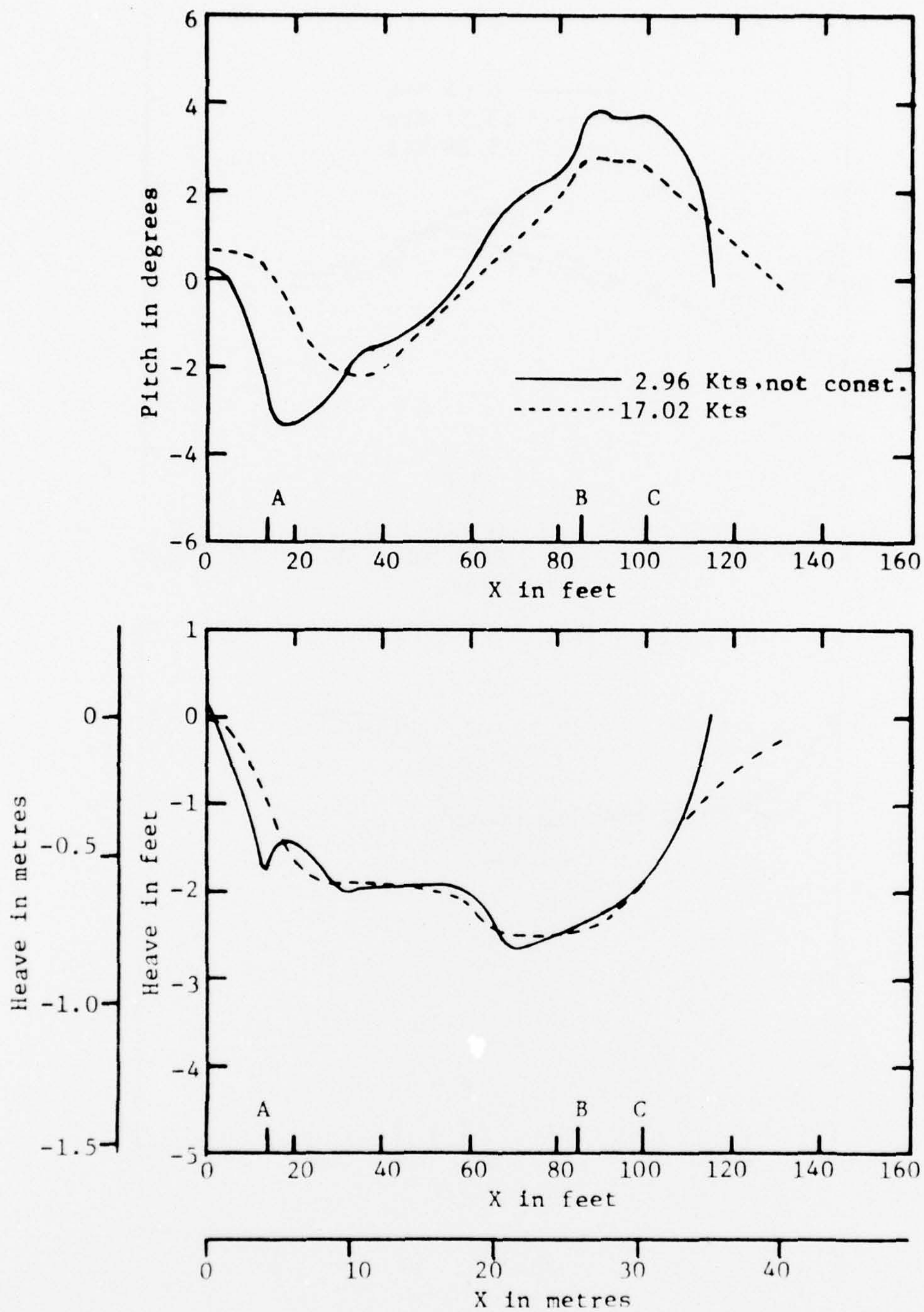


Figure 10 - The Jeff A AALC Encountering a 4.36 Metre by 1.81 Metre Gully for Two Speeds.

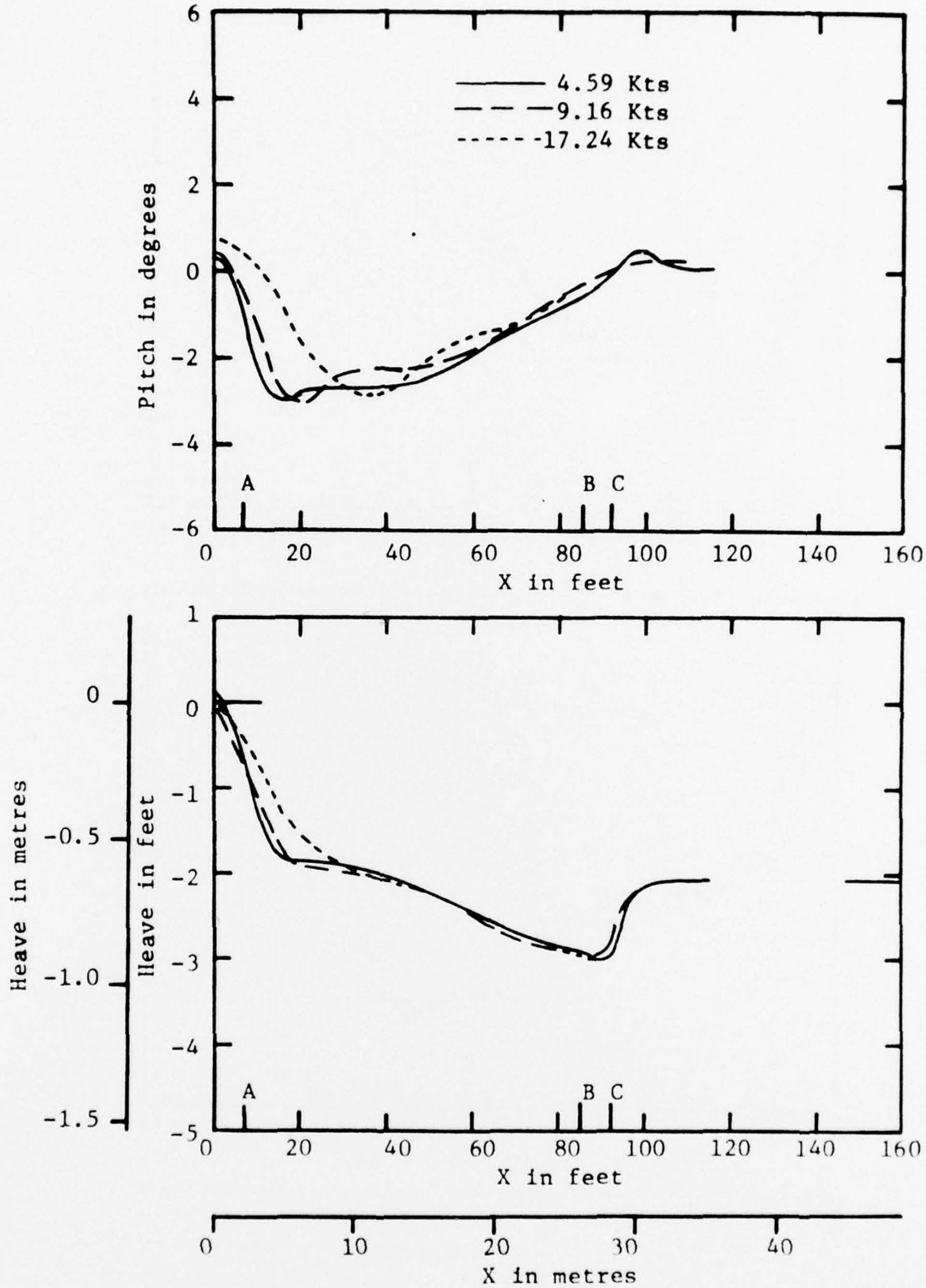


Figure 11 - The Jeff A AALC Encountering an Uneven Gully of 2.18 Metres in Length and From 1.81 Metre to 1.18 Metre in Height for Three Speeds.

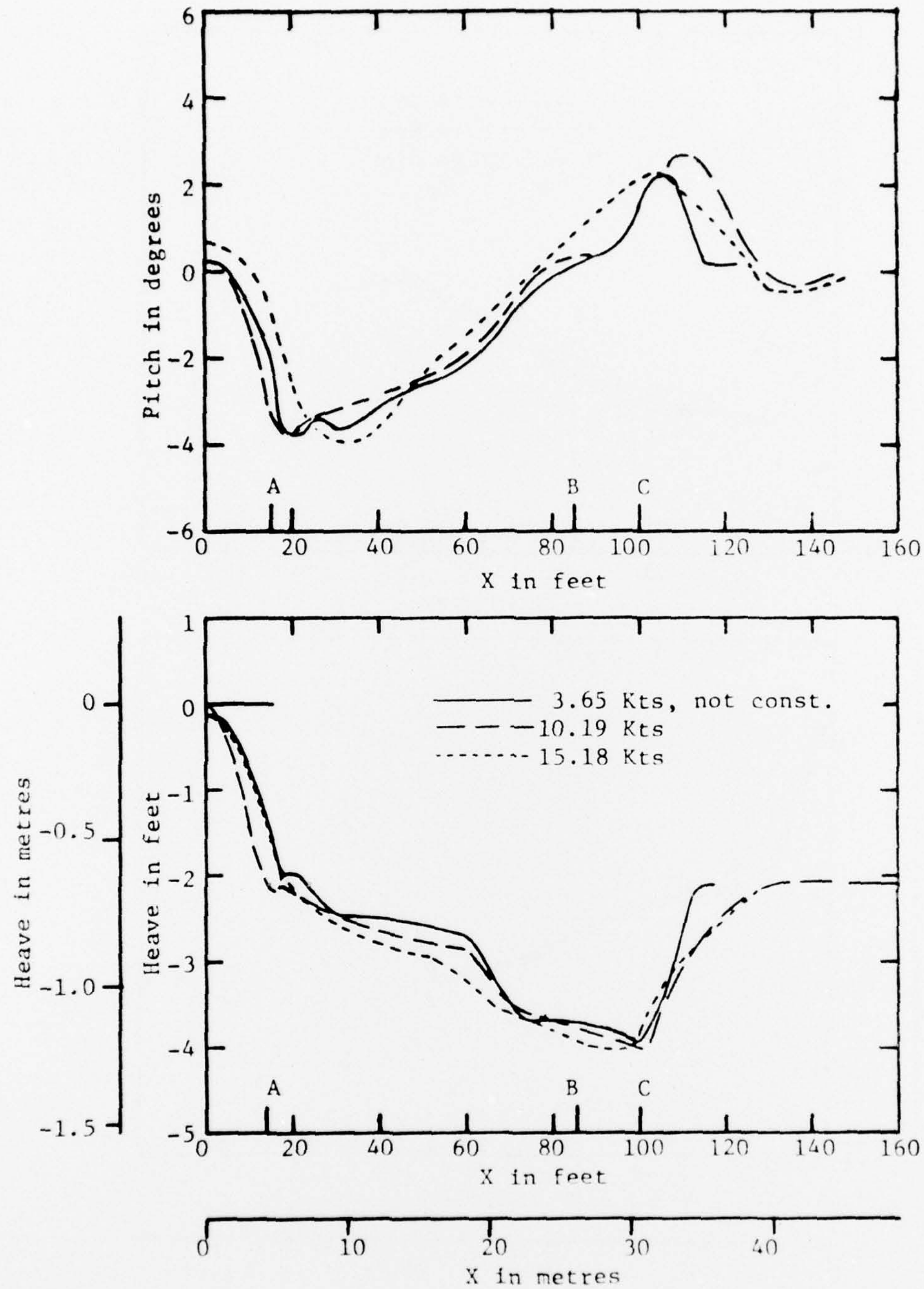


Figure 12 - The Jeff A AALC Encountering an Uneven Gully of 4.36 Metres in Length and From 1.81 Metre to 1.18 Metre in Height for Three Speeds.

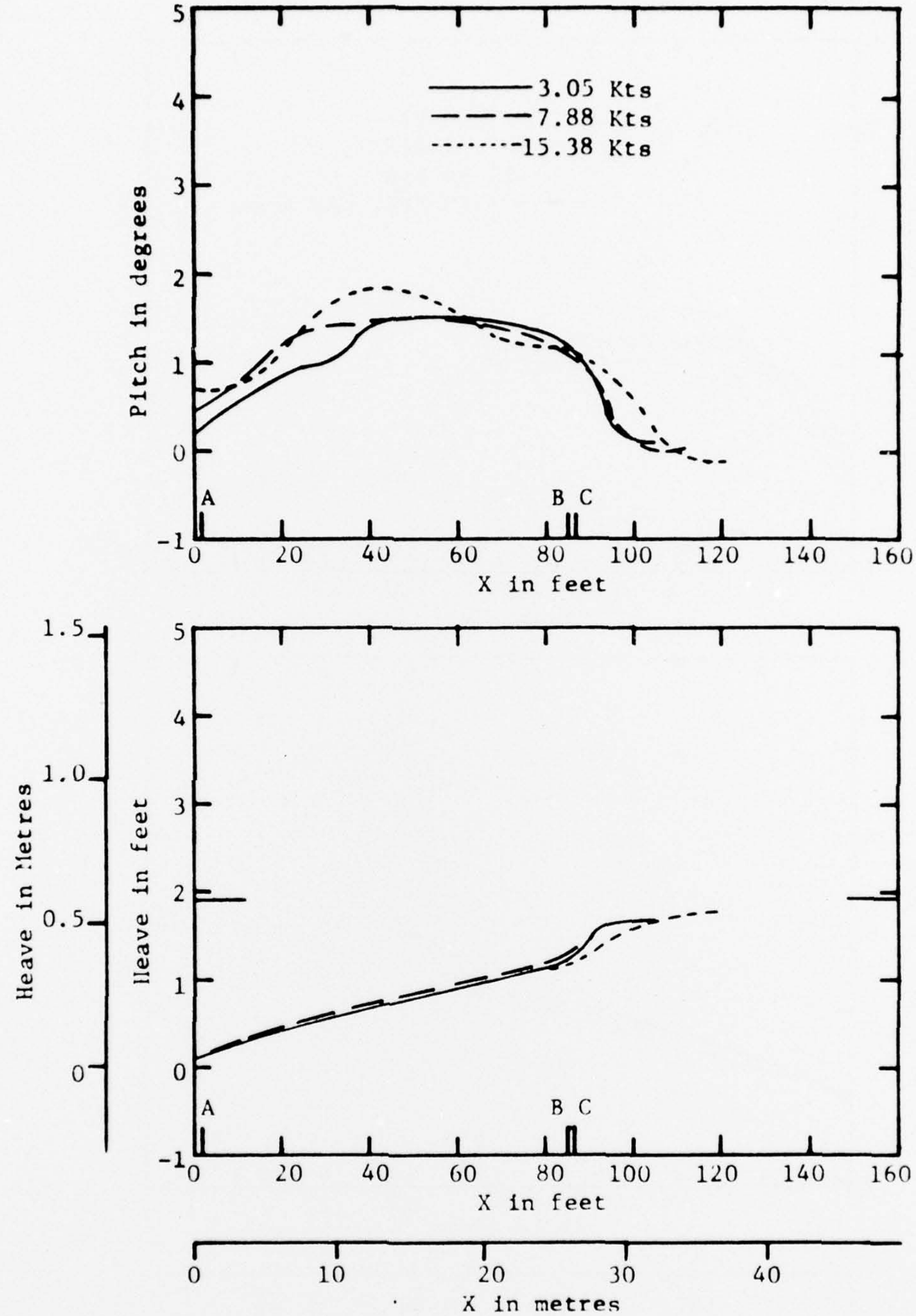


Figure 13 - The Jeff A AALC **Ascending a** 45 **Degree Ramp** of 0.55 Metres in Height for Three Speeds.

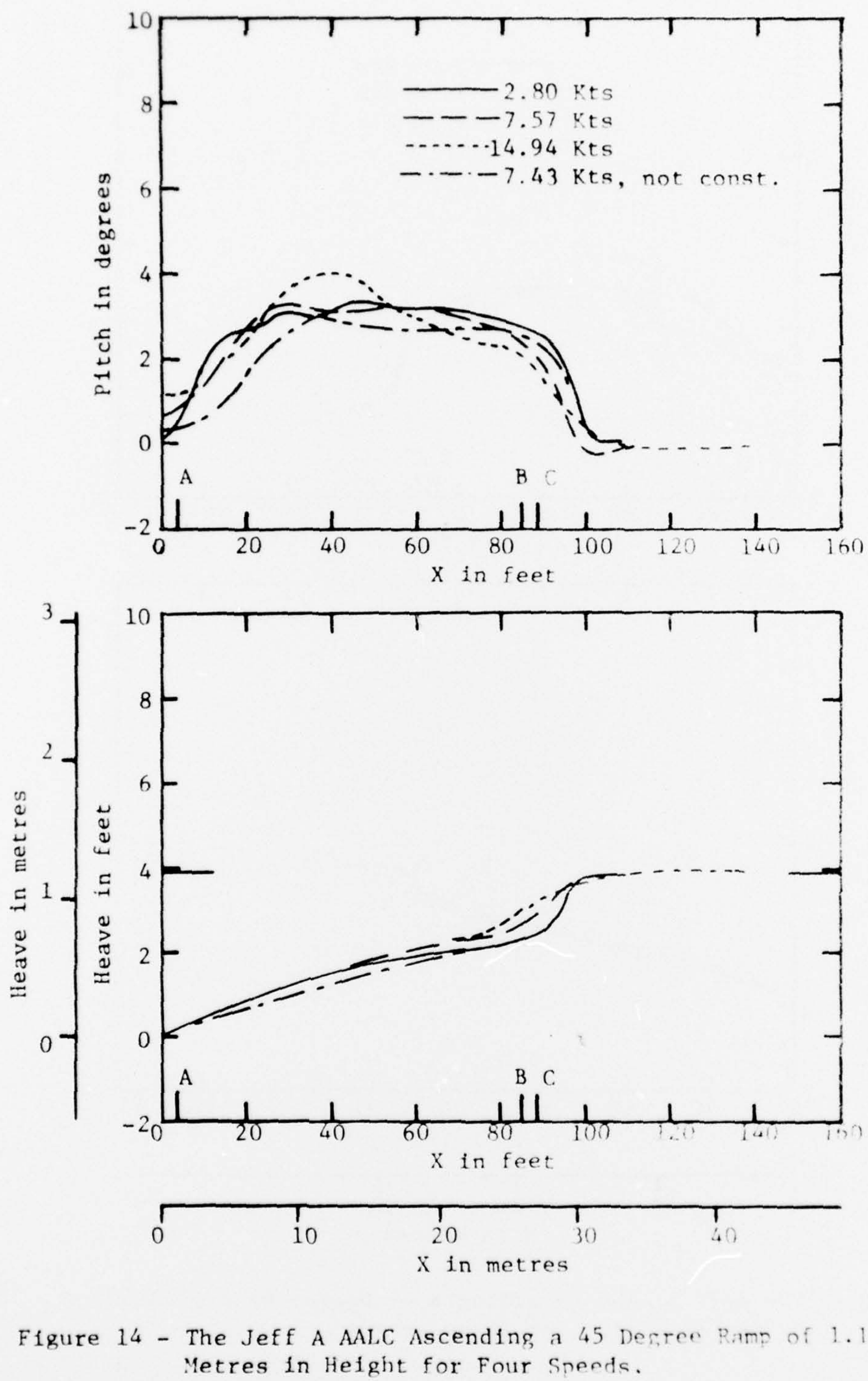


Figure 14 - The Jeff A AALC Ascending a 45 Degree Ramp of 1.18 Metres in Height for Four Speeds.

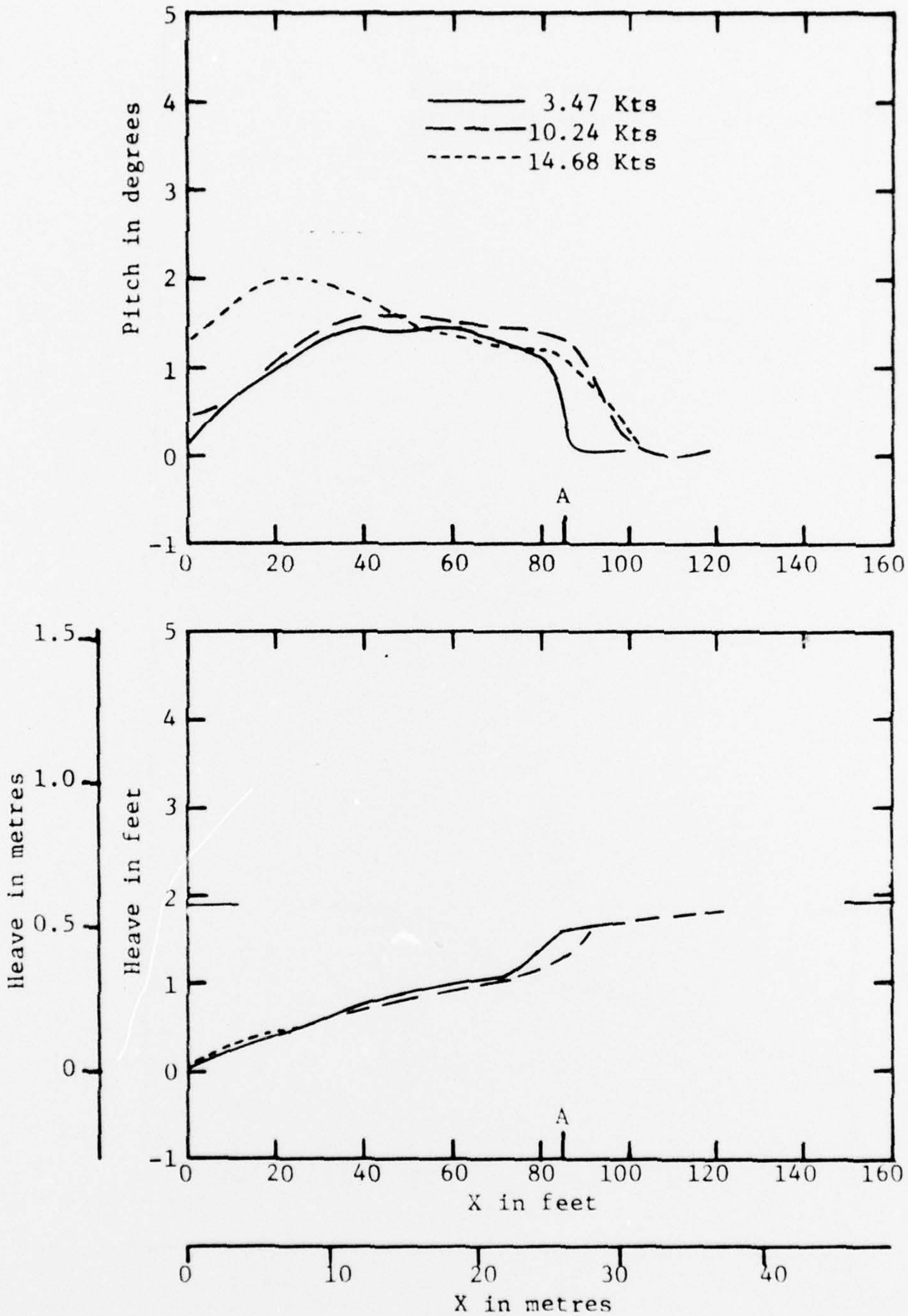


Figure 15 - The Jeff A AALC Ascending a 0.55 Metre Step for Three Speeds.

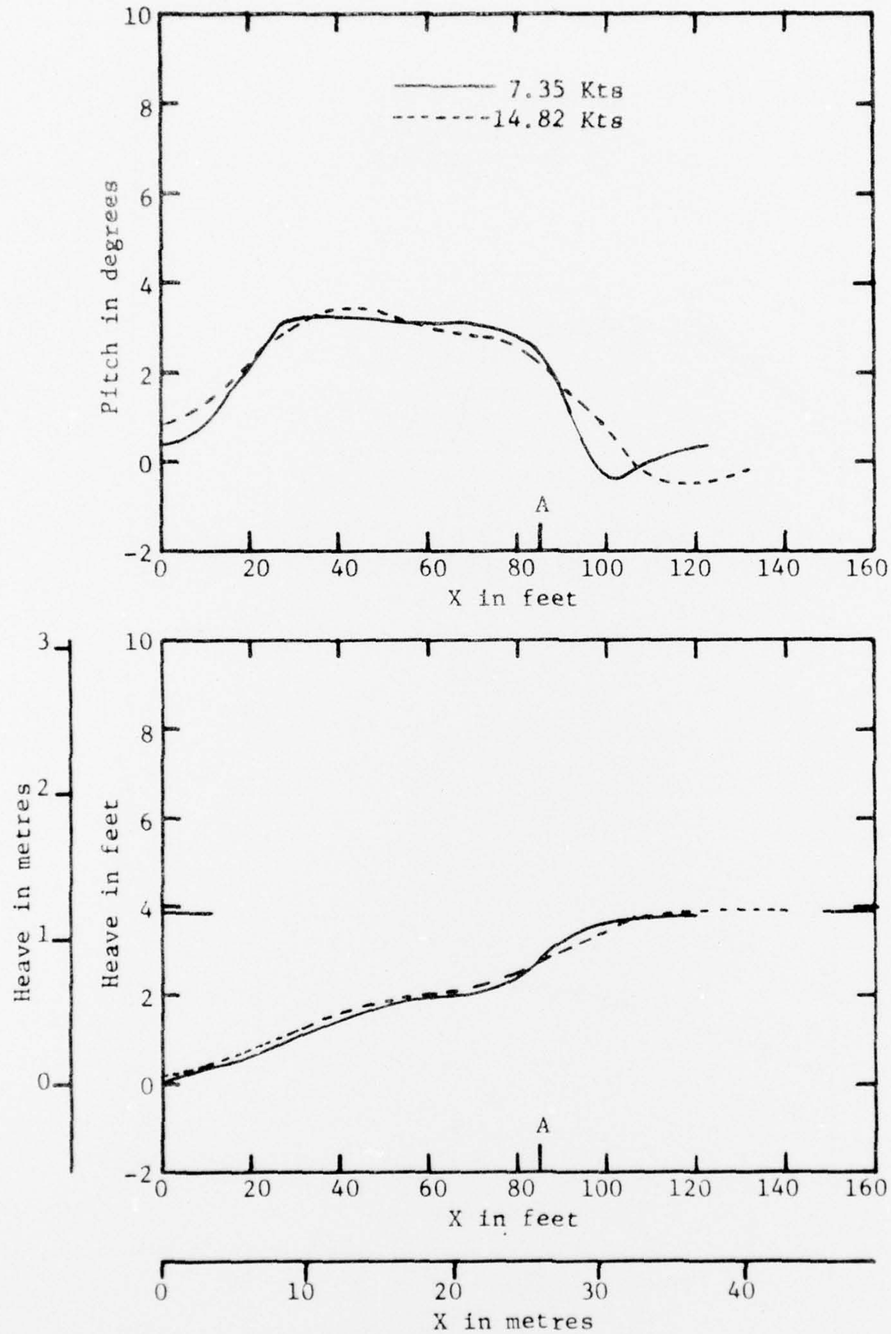


Figure 16 - The Jeff A AALC Ascending a 1.18 Metre Step for Two Speeds.

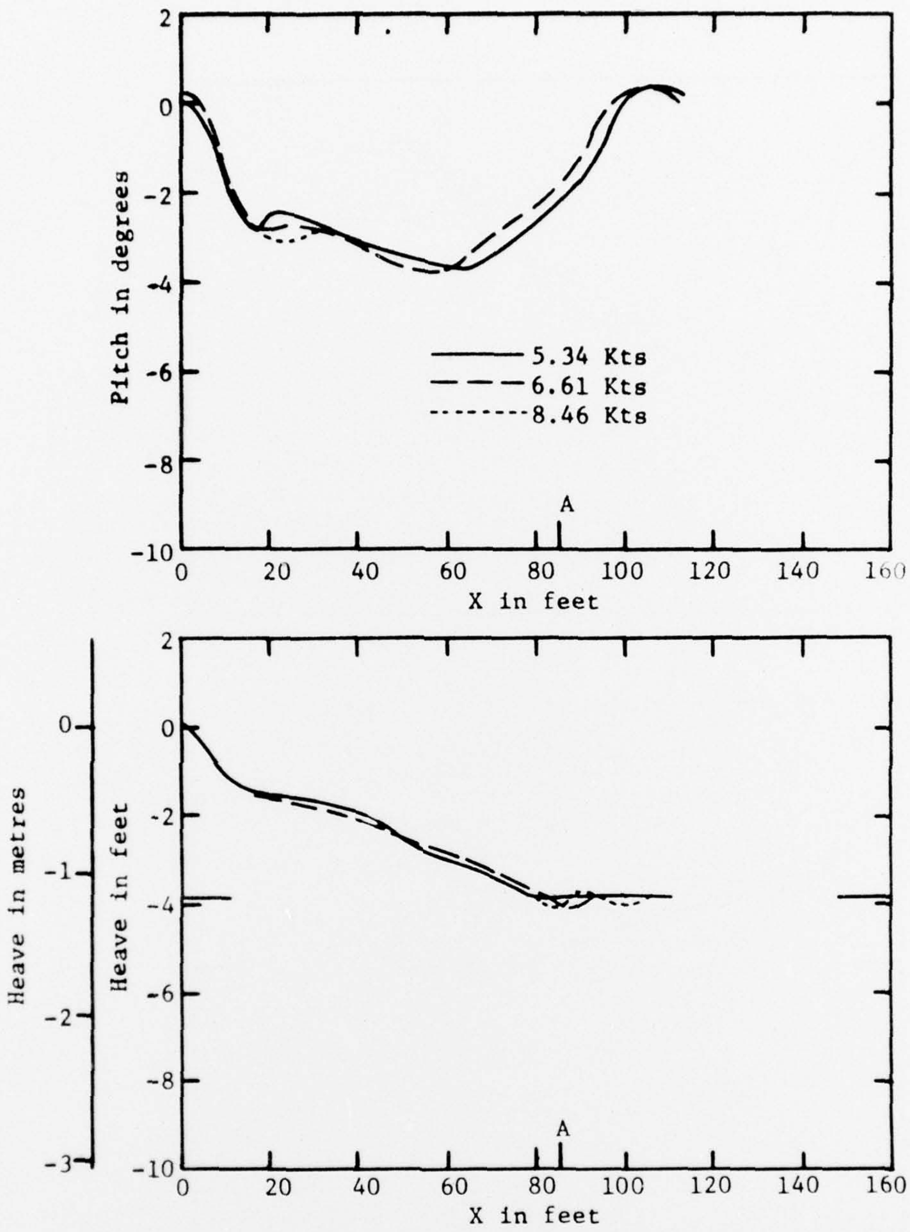


Figure 17 - The Jeff A AALC Descending a 1.18 Metre Step for Three Speeds.

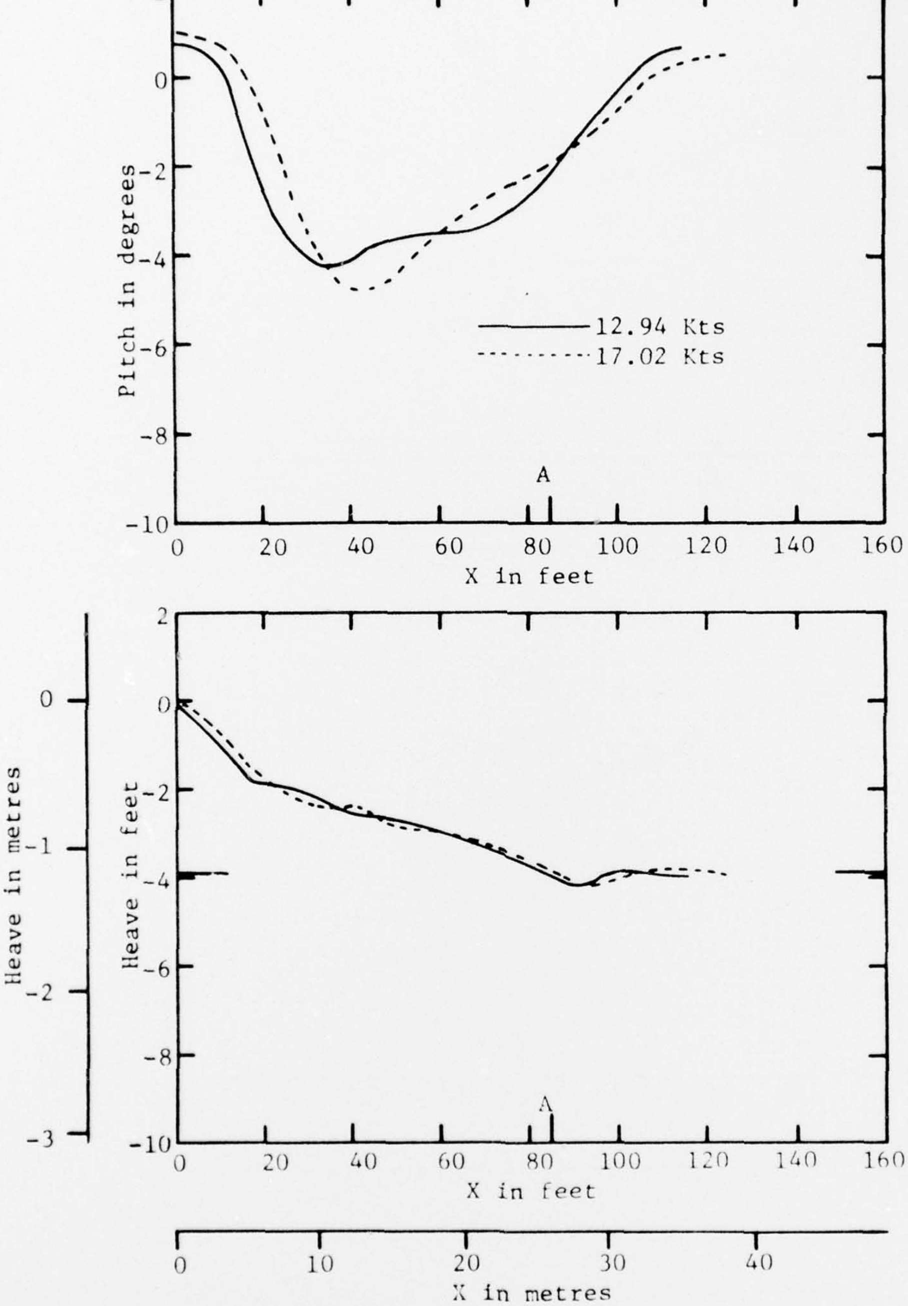


Figure 18 - The Jeff A AALC Descending a 1.18 Metre Step for Two Speeds.

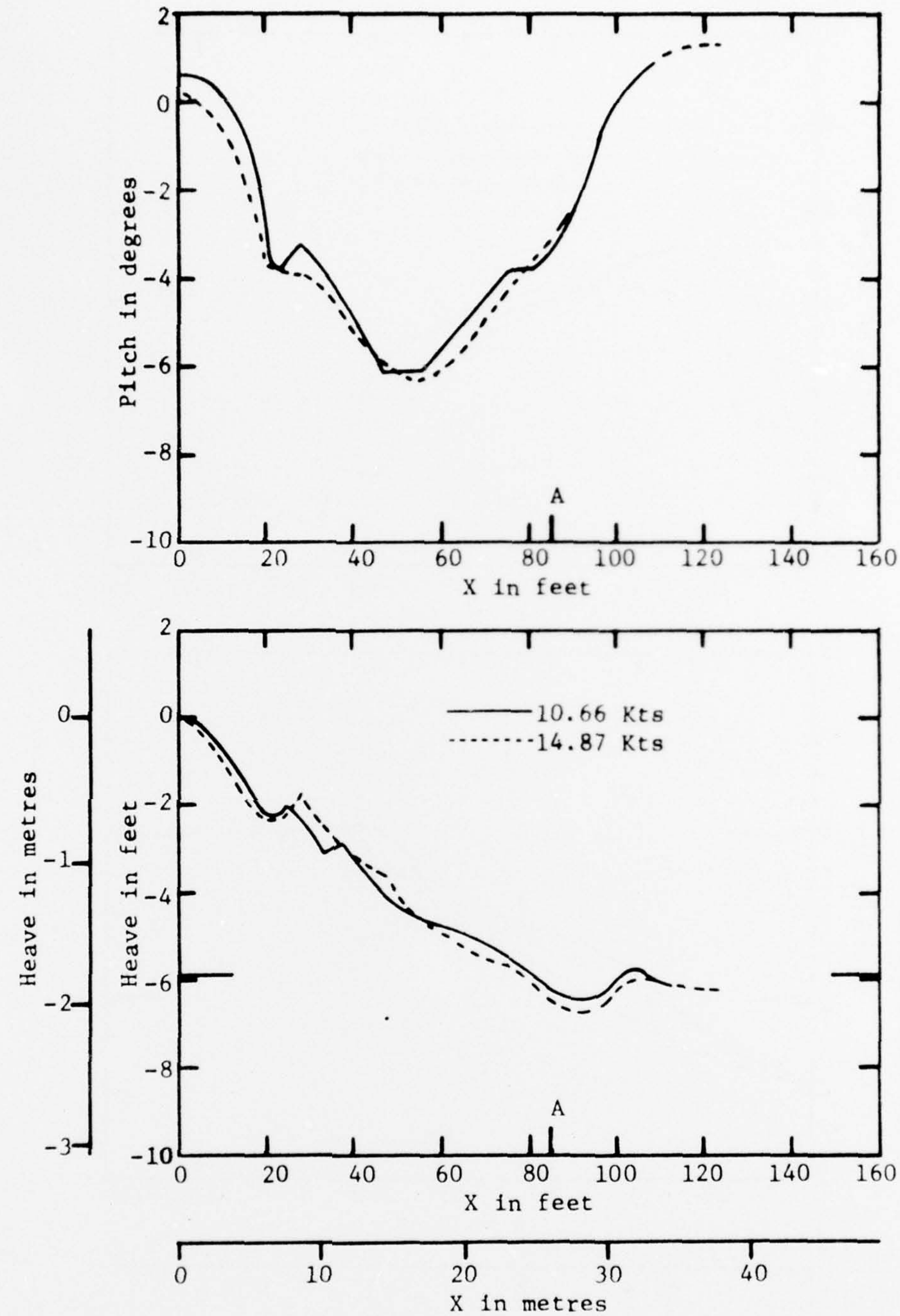


Figure 19 - The Jeff A AALC Descending a 1.81 Metre Step for Two Speeds.

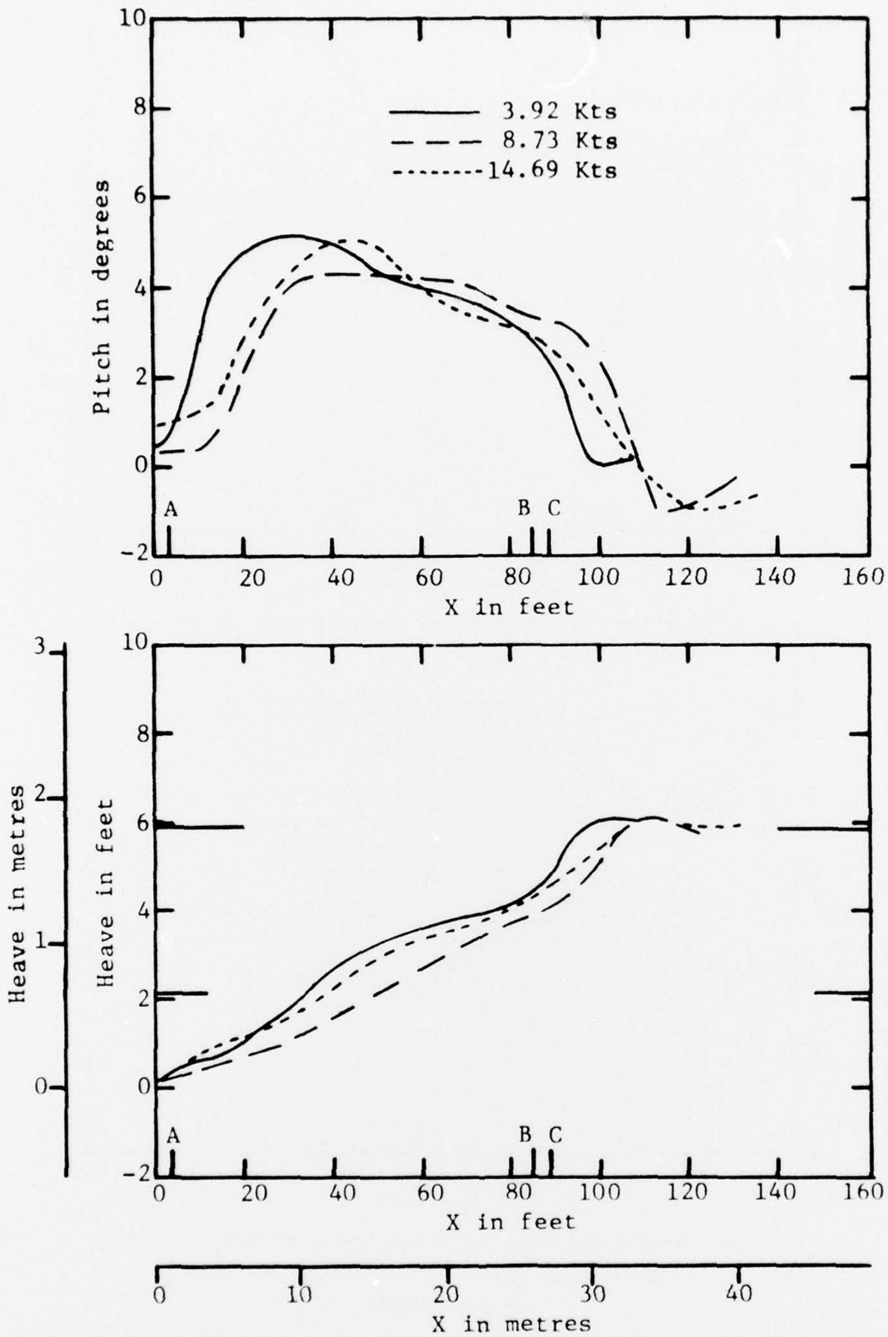


Figure 20 - The Jeff A AALC Ascending a 0.63 Metre Step With a 1.18 Metre High 45 Degree Ramp on Top for Three Speeds.

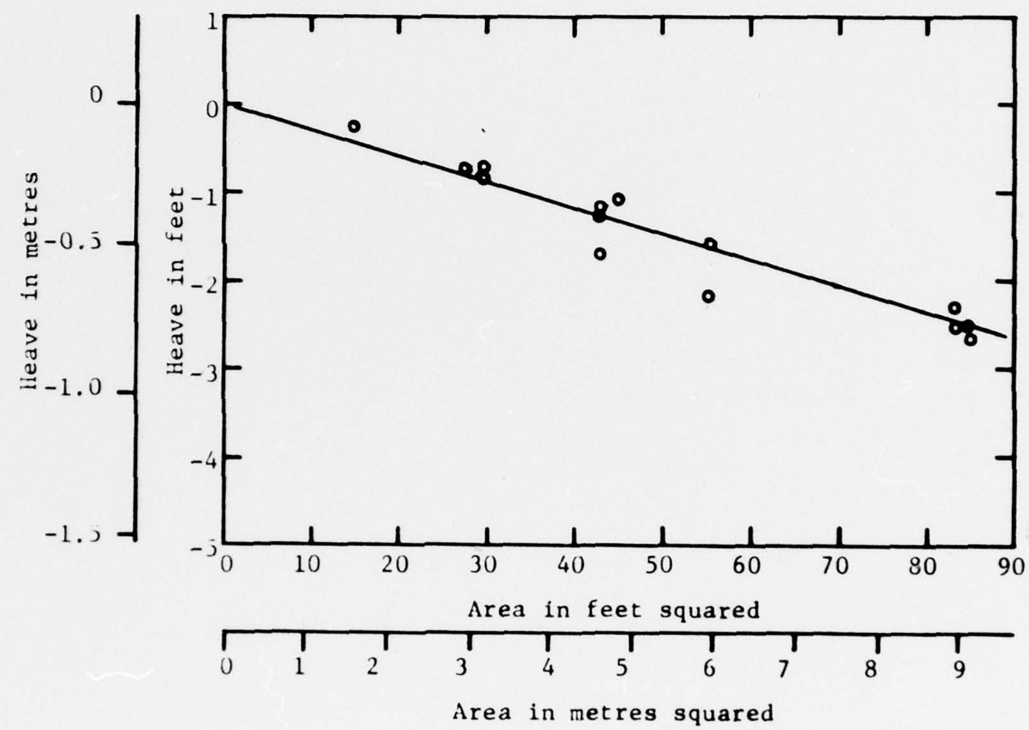


Figure 21 - **Heave** as a function of Gulley Area (Length x Depth) for **the** Jeff A AALC.

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